IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants: Sluijter et al.

Serial No.: TBA

Filed: Herewith

For: METHOD AND APPARATUS FOR ALTERING NEURAL TISSUE FUNCTION

Continuation of: 08/671,927, filed 6/27/96

Box Patent Application
Assistant Commissioner for Patents
Washington, DC 20231

TRANSMITTAL LETTER

Enclosed for filing are the following documents:

1. Preliminary Amendment;
2. Continuation Application 23 pages, including cover sheet (1 page); specification (15 pages), Abstract of the Disclosure (1 page), and claims (6 pages);
3. Three sheets of drawings including Figs. 1-8;
4. Verified Statement Claiming Small Entity Status;
5. Associate Power of Attorney; and
6. Combined Declaration and Power of Attorney.

Please charge the fee of $488 ($380 for the basic filing fee and $108 for twelve claims in excess of twenty) to our deposit account no. 08-0219. Please also charge any additional fee due or credit any overpayment in connection with this matter to our deposit account.

EXPRESS MAIL LABEL NO. EL719836505US

DATE OF DEPOSIT Oct. 1, 1999

Please send all correspondence to:

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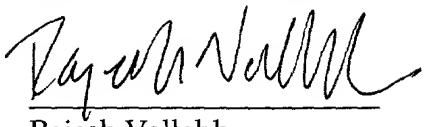
Respectfully submitted,



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October 1, 1999

Attorney Docket No.: 108.155.117

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Title: METHOD AND APPARATUS FOR ALTRING NEURAL TISSUE FUNCTION

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(d) and 1.27(c)) - SMALL BUSINESS CONCERN

I declare that I am an official of, and am empowered to act on behalf of Radionics, Inc. which qualifies as a small business concern as defined in 37 CFR 1.9(c) for purposes of paying reduced fees under Sections 41(a) and (b) of Title 35, U.S.C., to the Patent and Trademark Office with regard to the above-identified invention.

Radionics, Inc. has exclusive rights to the invention and has not assigned, granted, conveyed or licensed, and is under no obligation under contract or law to assign, grant, convey or license, any rights in the invention to any person or entity that could not be classified as a small entity under 37 CFR 1.9(c)-(e).

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b)).

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

Name of Official: Eric R. Cosman
Title of Official: President

Signature of Official

September 28, 1999
Date

EXPRESS MAIL LABEL NO. EL717836505US
DATE OF DEPOSIT Oct. 1, 1999

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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PRELIMINARY AMENDMENT

Prior to examination of this continuation application, please amend the application as follows:

In the Specification:

On page 1, before "BACKGROUND OF THE INVENTION" please insert the following:

--RELATED APPLICATION

This application is a continuation of Application Serial No. 08/671,927 filed on June 27, 1996.--

On page 4, line 23, please change "modd" to –mood--.

In the Claims:

Please cancel original Claims 1-8 and add the following new Claims 9-40:

EXPRESS MAIL LABEL NO. EL171836505US
DATE OF DEPOSIT Oct. 4, 1999

9. A method for sustained neural function modification in a patient comprising:

generating an amplitude modulated signal having at least one frequency component above a physiologic stimulation frequency range; and

applying the amplitude modulated signal to selected neural tissue in the patient for altering a function of the tissue without heating the tissue to temperatures lethal to the tissue, wherein the function remains altered for a given period of time after application of the signal to the tissue is ceased.

10. The method of Claim 9 wherein altering the function of the tissue reduces pain experienced by the patient.

11. The method of Claim 9 wherein altering the function of the tissue reduces pain by tremor experienced by the patient.

12. The method of Claim 9 wherein altering the function of the tissue reduces symptoms of Parkinson's disease experienced by the patient.

13. The method of Claim 9 wherein altering the function of the tissue reduces symptoms of spasticity experienced by the patient .

14. The method of Claim 9 wherein altering the function of the tissue reduces symptoms of mood disorder experienced by the patient.

15. The method of Claim 9 wherein altering the function of the tissue reduces symptoms of epilepsy experienced by the patient.

16. The method of Claim 9 wherein altering the function of the tissue alleviates motor disfunction.

17. The method of Claim 9 wherein the at least one frequency component of the amplitude modulated signal alters the function of the tissue.

18. The method of Claim 9 wherein applying the amplitude modulated signal to the tissue comprises engaging the tissue with an electrode coupled with a signal generator generating the amplitude modulated signal.

19. The method of Claim 9 wherein temperatures lethal to the tissue are greater than 45° C.

20. The method of Claim 9 wherein the at least one frequency component has a frequency greater than 300 Hz.

21. An apparatus for sustained alteration of a function of selected neural tissue in a patient comprising a signal generator and an electrode coupled to the signal generator, said signal generator being adapted to generate an amplitude modulated signal having at least one frequency component above a physiologic stimulation frequency range, said electrode being adapted to apply the signal to the tissue, wherein application of the amplitude modulated signal to the tissue alters a function of the tissue while inhibiting heating of the tissue to temperatures lethal to the tissue, and wherein alteration of the function of the tissue persists even after application of the signal to the tissue ceases.

22. The apparatus of Claim 21 wherein altering the function of the tissue reduces pain experienced by the patient.

23. The apparatus of Claim 21 wherein altering the function of the tissue causes the patient to experience a reduction in pain by tremor.

24. The apparatus of Claim 21 wherein altering the function of the tissue causes the patient to experience reduced symptoms of Parkinson's disease.

25. The apparatus of Claim 21 wherein altering the function of the tissue causes the patient to experience a reduced symptoms of spasticity.

26. The apparatus of Claim 21 wherein altering the function of the tissue causes the patient to experience a reduced symptoms of mood disorder.

27. The apparatus of Claim 21 wherein altering the function of the tissue causes the patient to experience a reduced symptoms of epilepsy.

28. The apparatus of Claim 21 wherein altering the function of the tissue alleviates motor disfunction.

29. The apparatus of Claim 21 wherein the at least one frequency component of the amplitude modulated signal alters the function of the tissue.

30. A method for lasting modification of neural tissue function in a patient comprising:

placing an electrode in or near selected neural tissue of the patient;

generating an amplitude modulated signal and transmitting the signal to the electrode, said signal having at least one frequency component above a physiologic stimulating frequency range for alteration of a function of the tissue without heating the tissue to temperatures lethal to the tissue, said alteration being sustained even after transmission of the signal to the electrode ceases.

31. The method of Claim 30 wherein altering the function of the tissue reduces pain experienced by the patient.

32. The method of Claim 30 wherein altering the function of the tissue causes the patient to experience a reduction in pain by tremor.

33. The method of Claim 30 wherein altering the function of the tissue causes the patient to experience reduced symptoms of Parkinson's disease.

34. The method of Claim 30 wherein altering the function of the tissue causes the patient to experience a reduced symptoms of spasticity.

35. The method of Claim 30 wherein altering the function of the tissue causes the patient to experience a reduced symptoms of mood disorder.

36. The method of Claim 30 wherein altering the function of the tissue causes the patient to experience a reduced symptoms of epilepsy.

37. The method of Claim 30 wherein altering the function of the tissue alleviates motor disfunction.

38. The method of Claim 30 wherein the at least one frequency component of the amplitude modulated signal alters the function of the tissue.

39. The method of Claim 30 wherein temperatures lethal to the tissue are greater than 45° C.

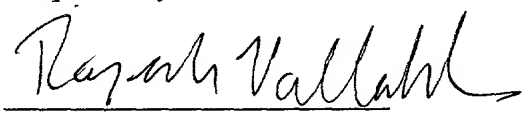
40. The method of Claim 30 wherein the at least one frequency component has a frequency greater than 300 Hz.

Remarks

Original Claims 1-8 have been cancelled, and new Claims 9-40 have been added in this continuation application. The specification has been amended to reference the parent application. It has also been amended to correct an obvious typographical error on page 4.

Support for the amendments is present in the original disclosure; no new matter has been added.

Respectfully submitted,



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Method and Apparatus for Altering Neural Tissue Function

by

Menno E. Sluijter, William J. Rittman, III,
and Eric R. Cosman

BACKGROUND OF THE INVENTION

The use of radiofrequency (rf) generators and electrodes to be applied near or in neural tissue for pain relief or functional modification is well known. For instance, the RFG-3C RF Lesion Generator of Radionics, Inc., Burlington, Massachusetts, and its associated electrodes enable placement of the electrode near neural tissue and heating of that tissue by rf resistive power dissipation of the generator power in the tissue. Thermal monitoring by thermo sensor in the electrode has been used to control the process. Heat lesions with tissue temperatures of 60 to 95 degrees Celsius (°C) are common. Tissue dies by heating at about 45 to 50°C, so this process is a heat lesion generation and is designed to elevate the neural tissue above this lethal temperature threshold. Often, the procedure of heating above 45 to 50°C causes severe pain to the patient which is so unpleasant and frequently unbearable that local or general anesthetic is required during the heat procedure. Use of such anesthetics has a degree of undesired risk to the patient, and the destructive nature of and unpleasant side effects of the rf heat lesion are limitations of this technique, which is well known. Heat lesion generators typically use continuous wave rf generators with radiofrequencies of between 100 KiloHertz to several MegaHertz (viz. the rf generators of Radionics, Fischer, OWL, Elekta, Medtronic, Osypka, EPT companies). The theory and use of rf lesion generators and electrodes for pain and functional disorders is described in various papers; specifically see: (1) Cosman, et al. "Theoretical Aspects of Radiofrequency Lesions and the Dorsal Root Entry Zone." *Neurosurg* 15:945-950, 1984; and (2) Cosman ER and Cosman BJ. "Methods of Making Nervous System Lesions," in Wilkins RH, Rengachary SS (eds): *Neurosurgery*. New York, McGraw-Hill, Vol. III, 2490-2498, 1984.

Neural stimulation is also now a common method of pain therapy. Stimulus generators with outputs of 0 to 10 volts (or zero to several milliamperes

of current criteria are used) are typical. A variety of waveforms and pulse trains in the "physiologic" frequency ranges of 0 to about 300 Hertz are also typical. This output is delivered to electrodes placed near or in neural tissue on a temporary basis (acute electrode placement) or permanent basis (chronic electrode implants). Such stimulation can relieve pain, modify neural function, and treat movement disorders. Typically, the stimulation is sustained to have a long-term effect, i.e. usually when the stimulus is turned off, the pain will return or the therapeutic neural modification will cease after a short time (hours or days). Thus permanent implant electrodes and stimulators (battery or induction driven) is standard practice (viz. see the commercial systems by Medtronic, Inc., Minneapolis, Minnesota), and the stimulus is usually sustained or repeated on an essentially continuous basis for years to suppress pain or to treat movement disorders (viz. Parkinsonism, bladder control, spasticity, etc.). Stimulators deliver regular pulse trains or repetitive bursts of pulses in the range of 0 to 200 Hertz (i.e., a physiologic range similar to the body's neural frequency pulse rates), so this method simulates or inhibits neural function at relatively low frequency. It does not seek to heat the neural tissue for destructive purposes as in high frequency technique. Chronically or permanently implanted stimulators often require battery changes or long-term maintenance and patient follow-up, which is expensive and inconvenient, often requiring repeated surgery.

Electrosurgical generators have been in common use for decades cutting and coagulating tissue in surgery. They typically have a high frequency, high power generator connected to an electrode that delivers a high power output to explode tissue for tissue cutting and to cook, sear, and coagulate tissue to stop bleeding. Examples are the generators of Codman, Inc., Randolph Massachusetts, Valley Labs, Inc., Boulder, Colorado, and EMC Industries, Montrouge, France. Such generators have high frequency output waveforms which are either continuous waves or interrupted or modulated waves with power controls and

duty cycles at high levels so that tissue at the electrode is shattered and macroscopically separated (in cutting mode) or heated to very high temperatures, often above cell boiling (100°C) and charring levels (in coagulation or cauterizing mode). The purpose of electrosurgery generators is surgical, not therapeutic, and accordingly their output controls, power range, duty cycle, waveforms, and monitoring is not designed for gentle, therapeutic, neuro-modulating, sub-lethal temperature application. Use of an electrosurgical unit requires local or general anesthetic because of its violent and high-temperature effect on tissues.

SUMMARY OF THE INVENTION

The present invention is directed to a modulated high frequency apparatus in conjunction with a signal applicator (for example an electrode or conductive plate or structure applied to the body) to modify neural function, the associated apparatus and method of use being functionally different from and having advantages over the rf heat lesioning systems, or the stimulation systems, and electrosurgical systems of the type described above. Pain relief or neural modification, for instance, can be achieved by the present invention system without average heating of tissue above 45 to 50°C, without stimulating at frequencies in the range of 0 to about 300 Hertz and without burning or cauterizing tissue. Thus as one advantage of the present invention, painful rf lesioning episodes at high lesion temperatures can be avoided and the need for chronic stimulation can be circumvented.

For example, by using an rf waveform output connected to an electrode inserted into the body near or in neural tissue, and by interrupting the rf waveform with bursts of rf power with interposed periods of off-time, a pain relieving effect or other neural modulating effect is accomplished, but the tissue temperature may not on average exceed approximately 45°C. This avoids the painful heat lesions associated with the typical rf lesions which involve tissue temperatures at a region near the electrode of substantially greater than 45°C. The modulated rf system can be used painlessly and easily, avoiding usual discomforts of standard rf heating procedures, yet relief of the pain or the neural disfunction (such as for example motor disfunction, spasticity, Parkinsonism, tremors, modd disorders, incontinence, etc.) can be long lasting using the novel system of the present invention, giving results in many cases that are comparable to those of rf heat lesions done at much higher temperatures. Some applications of this invention may include such examples as relief of back, head, and facial pain by procedures such as dorsal root ganglion or trigeminal ganglion treatments, spinal

cord application for relief of intractable pain, spasticity, or motor control, treatment of the basal ganglia in the brain for relief of Parkinsonism, loss of motor control, tremors, or intractible pain. This pain relief or control or elimination of motor or other neural disfunction can be comparable if not more effective than long-term stimulators with implanted electrodes, thus avoiding the need for permanent implants, expensive implanted devices and circuits, battery changes, involving repeated surgery and expense, and repeated application of stimulation energy over long periods (months and years). The pain relief or neural modification can be accomplished by the present invention in a non-violent, painless way, avoiding average tissue temperature elevations into the lethal range and violent macroscope tissue separations, and thus the present invention is opposite to the objectives, systems, and methods involved in electrosurgical systems.

Forms of the modulated frequency generator and output waveforms are disclosed herein in various embodiments. Specific embodiments with temperature monitors and thermal sensing electrodes are disclosed which are suited to control the modulated system and its use.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, which constitute a part of the specification, exemplary embodiments exhibiting various forms and features hereof are set forth, specifically:

FIGURE 1 is a block diagram of elements of a system in accordance with the present invention.

FIGURE 2 is a graphical representation of an interrupted rf waveform output from an rf generator system in accordance with the present invention.

FIGURE 3 shows a graph of a modulated frequency waveform of the present invention.

FIGURE 4 illustrates an irregular frequency output waveform in accordance with the present invention.

FIGURE 5 shows a repeated frequency signal with lowered output duty cycle.

FIGURE 6 is a block diagram of elements of a system for generating modulated frequency signals.

DESCRIPTION OF THE INVENTION

Referring to FIGURE 1, an illustration of the present invention is shown in block diagram and schematic elements. An electrode with uninsulated conductive surface 1 (for example a conductive tip end) is in proximity to a region of neural tissue NT (viz. illustrated schematically by the dashed boundary). The electrode has an insulated shaft 2 and connection or hub portion 3, inside of which there can be electric connections to surface 1. Connection 10 electrically connects to the surface 1 through the electrode shaft 2 and to electronic supply units 4 and 5 (which are shown outside the body, but which may be miniaturized and implanted inside the body). Element 5 is a signal generator of signal output (viz., voltage, current, or power), and element 4 is a modulator to modulate (for example the amplitude of) the high frequency output from 4. The electromagnetic output from 4 and 5 is connected to electrode surface 1, and therefore is conductively exposed to tissue NT. As an example, element 5 can take the form of an rf power source with a continuous wave output (viz. for example, similar to the model RFG-3C generator of Radionics, Inc., Burlington, Massachusetts). Element 4 is a pulse modulation unit which switches on and off the rf output from 5 at a designed rate and duty cycle. RF output generators or supplies and modulation circuits are known in high frequency technique (viz. *Radio Engineering* by Fredereck E. Terman, McGraw-Hill, New York, 1947, 3rd Edition). Further shown is a temperature monitoring element or circuit 6 which connects by cable 11 to the electrode and to a thermal sensor (viz. thermistor or thermocouple) inside the electrode applicator or conductive tip 1 to measure the temperature of the tissue NT near the tip. (Such thermal sensing circuits and electrodes are illustrated by the Model RFG-3C and associated thermal-sensing rf electrodes of Radionics, Inc., Burlington, Massachusetts). Further, reference electrode 8 is shown in electric contact to the patient's body B with connection

wire 12 to generator 5 so as to provide a circuit for return current from electrode applicator 1 through the patient B (such reference electrodes are common with rf lesion generators; see Cosman, et al., 1984). Element 7 is a switch or circuit breaker which illustrates that such a return circuit could be opened to limit such direct return current, and limit such current to inductive or reactive current characteristic of time varying circuits such as rf circuits.

In operation, the voltage or current output from generator 4 and modulator 5 are impressed upon tissue NT, which may be neural tissue (viz. spinal nerves or roots, spinal cord, brain, etc.) or tissue near neural tissue. In accordance with the present invention, such electromagnetic output can cause energy deposition, electric field effects, and/or electromagnetic field effects on the nerve cells in the tissue NT so as to modify or destroy the function of such nerve cells. For example, such modification of neural function may include reduction or elimination of pain syndromes (such as spinal facet, mechanical back pain, facial pain) in some cases, alleviating motor disfunction, spasticity, Parkinsonism, etc., epilepsy or mood disorders. Because the rf output from 4 is modulated by element 5, its percent on-time is reduced so that sustained heating of tissue NT is reduced, yet the neural therapeutic effects of the impressed rf voltages and currents on the neural tissue NT are enough to produce the pain reducing result. The generator 5 can have a power, voltage, or current output control 5A (as on the Radionics Model RFG-3C rf generator) to increase or decrease the output power magnitude or modulated duty cycle to prevent excessive heating of tissue NT or to grade the level of pain interruption as needed clinically. Output control 5A may be a knob which can raise or lower the output in a smooth, verniated way, or it can be an automatic power control with feedback circuits. In this regard, temperature monitor 6 can provide the operator with the average temperature of tissue NT near electrode tip 1 to interactively prevent temperatures near tip 1 to exceed the range of approximately 45°C (on average thermally lethal to tissue NT), and thus

to avoid the higher temperature ranges for the usual heat lesioning procedures described above. For example, 6 may have feedback circuitry to change the modulation duty cycle (by, for example, longer or shorter on-times) to hold the temperature near tissue NT to below a set value (viz. 40 to 45°C), illustrated by the feedback line 14 in Figure 1. In addition, the high frequency waveform from the generator 5 can be free from substantial components in the 0 to about 300 to 400 Hertz range (which is much lower than radiofrequencies), and this will avoid the stimulation effects that are typical for stimulator system applications as described above.

As an example of a modulated rf waveform that accommodates the system of the present invention, Figure 2 shows schematically a high frequency output of voltage amplitude V and of burst duration T1 between which on-time bursts there are illustrated periods of zero voltage of duration T2. During the on-time T1, the rf signal output is oscillatory with time period T3 between maximum voltages V. The reciprocal of T3 is proportional to the value of the radiofrequency (viz., 1 Mega Hertz rf output corresponds to T3 = 1 microsecond). This is an interrupted or bursting type of modulated high frequency waveform. During the high frequency on-time T1, the voltage can oscillate between plus and minus its maximum value V. Accordingly, an electric field is produced around the region of the electrode applicator (as for instance the exposed electrode tip 1 in FIGURE 1). The electric field has a modifying, or pain-relieving, or neural-altering effect on the tissue near or among the nerve cells and fibers. Pain relief and neural modification can accordingly be accomplished by this high frequency bursting voltage and accompanying electromagnetic field, and also accompanying current among the neural and tissue cells. During the off period, there is minimal or no voltage (i.e. V=0 at the electrode applicator), and thus no electric field or electric currents in and among the neural tissue. During that period, no heat deposition is present. Thus, over the entire cycle, from on period T1 through off period T2,

the energy deposition, on average, can be adjusted so that there is not excessive heating, on average, around the electrode applicator. Thus, the usual mechanism of continuous on-time high frequency voltage and current, as in previous heat lesion techniques, is avoided, and therefore the achievement of high average temperatures near or around the applicator tip may be eliminated by the present invention. The usual heat lesion process in which tissue temperatures, on average, exceed 45° can be avoided. In many instances, this avoidance of high temperature domains due to high average heat dissipation of the radiofrequency power will prevent acute pain of the process to the patient. By having the interrupted waveform, as in FIGURE 2, the average power is thereby reduced and the average heating around the electrode tip or applicator is accordingly reduced. However, substantial voltages V (or currents) can still be sustained during the on period with their resulting therapeutic effect on the tissue.

To give a representative example of values for parameters in an interrupted high frequency waveform as in FIGURE 2, the overall pattern of the waveform may have a total period of one second, meaning that the sum of T1 + T2 = 1 second. The on period T1 can be 20 milliseconds, and the off period T2, therefore, can be 980 milliseconds. Voltages V in the range of 10 to 30 volts or more can be used. It can be used with a pain relieving effect in certain tissues. Average tip temperature around an electrode tip such as the exposed tip element 1 in FIGURE 1 can be maintained at or below 40°C, well below thermo-lethal levels. Electrodes with diameters of 1 or 2 mm shaft (for example the shaft 2 of a cannula in FIGURE 1), with an exposed tip of 1 to 10 mm (such as the tip element 1 in FIGURE 1) can be used and the electrode can be inserted in around neural structures in the brain or peripheral nerves or peripheral nerve ganglia to accomplish pain relief or other neurological alteration. Variation of these parameters can be made with similar therapeutic effect, and various geometries of conductive electrode or applicator can be effective. Illustrations of a wide variety of such electrodes are illustrated by

the product line of Radionics, Inc., Burlington, Massachusetts. Pointed or sharpened electrodes (such as illustrated schematically by electrode tip 1 in FIGURE 1) are useful for penetration of the electrode through the skin to the target neural tissue site, and electric or current fields of higher intensity will be present at a sharpened point for a given applied voltage (such as V in FIGURE 2), which will be effective in altering neural function.

FIGURE 3 shows a variation of modulated high frequency waveform which accomplishes high peak voltage swings with reduced average power deposited in tissue. The baseline voltage may be put at zero (viz. V=0), shown by dashed line 24. The solid line 21 represents the actual waveform, which has rapid oscillations at the radiofrequency and has an overall envelope represented by dashed line 20, that has high points and low points with an approximate on time T1 and a time period between envelope of modulation maxima T2. T1, again, could be a percentage on time of 2 percent (as described above for 20 milliseconds on time out of 1 second total), and this on time T1 may vary considerably while still maintaining substantial off time so as to prevent overall average high temperature heating (as in the usual rf heat lesion systems). Such a modulation envelope (as dashed line 20) can be achieved by using a modulated signal generator that varies the input or output gain of a high frequency generator (as element 5 in FIGURE 1) so as to achieve such a waveform as in FIGURE 3. In such circuitry, which is commonly used in pulse generation techniques, low frequency filtering or selection of modulation parameters can avoid stimulation voltage or current components at the physiologic range of 0 to 300 Hertz so that unpleasant stimulative effects can be avoided during the therapeutic intermittent high frequency lesion process.

FIGURE 4 shows yet another embodiment of an interrupted high frequency waveform in accordance with the present invention. Here there is a non-periodic variation of the voltage represented by the excursions of the voltage V represented

by excursions on a vertical axis. The maxima point 25 can occur at random positions in time. The time difference between maxima can also vary in an irregular or even random way. This waveform may have no repeating or periodic structure but may be analogous to high frequency noise with random amplitudes, peaks, zero crossings, and carrier high frequencies. Such a waveform can be generated by random noise generators, spark gap signals, or other noisy signals that are known in the field of signal generation (viz. *Radio Engineering*, cited above). Filtering can be applied in the wave generator and power amplifier so that lower frequencies in the physiologic range will not be present to give undesirable stimulation effects.

FIGURE 5 shows yet another possible high frequency waveform of interrupted, repeated bipolar pulses with frequency repetitive T3 for example the physiologic stimulation frequency range (i.e., 0 to about 300 Hertz). The pulse on-time may be low enough so that the power deposition can be kept low enough to prevent heating, and yet the peak voltage V is enough to alter the neural function.

Variations of such waveforms are possible with the same intermittent high frequency effect for pain on neurological modification. For instance, a baseline V=0 may not pertain and a slowly varying baseline of non-zero value can be used. The time average of the signal need not be zero. The on and off switching of a high frequency signal such as in FIGURE 2 can be done at a non-periodic or non-regular, repeating rate so that, on average, the polarization effects in the tissue are still maintained at a low level. The average power deposition can still be maintained at a low level with non-periodic, interrupted high frequency waveforms. The high frequency carrier frequency (i.e. represented by the inverse of time T3 in FIGURE 2 and FIGURE 3) may also be non-constant. Varying or combined or superposed high frequency waveforms can be used as the carriers, and these combined or composite high frequency waveforms can be interrupted or

modulated in accordance with the present system and invention. Pulse waveforms with high frequency carriers can be shaped in a variety of ways, for example with fast rising leading edges and slow or falling off or exponential trailing edges. The signal generator waveform can have a peak intensity which is much higher than the average or RMS intensity to yield a high electromagnetic field or current density on the neural tissue while maintaining the average power deposition in the tissue at a sufficiently low level to prevent heating above lethal tissue temperatures (viz. 40 to 50°C).

FIGURE 6 shows a block diagram of a system for generating modulated high frequency signals (similar but in more detail to the block element of high frequency generator 5 and modulator 4 of FIGURE 1).

Element 50 represents a signal generator which may create a high frequency signal of periodic or non-periodic frequency. This has input to element 31, which is a filter system which selectively filters out frequencies that could cause unpleasant, undesired, or damaging physiological signals. The signal is then fed into element 33, which is a waveform shaping circuit, and will shape the waveform input from element 32, which provides amplified modulation and/or frequency modulation and/or phase modulation control. Circuits of this type can be found, for instance in *Radio Engineering* by Terman (cited above). Additional waveform shaping can be done by element 40 and 41, which can control the amplitude of waveform and/or the duty cycle of the waveform, espectively. This resultant signal is then fed into a power amplifier represented of element 34. This is a wide band amplifier used to increase the signal to power levels appropriate for clinical use. This energy is then delivered to the patient via an electrode depicted as element 35.

A temperature sensor or plurality of temperature sensors, represented by element 36, can also be placed and connected in proximity to this electrode so as to

insure that the temperature does not exceed desired limits. This temperature sensor signal is fed through element 37, which is a special filter module used to eliminate high frequency components, and thus not to contaminate the low-level temperature signals.

The temperature signal is fed to element 38, which is a standard temperature measuring unit that converts the temperature signal into a signal that can be used to display temperature and/or to control, in a feedback manner, either the amplitude and/or the duty cycle of the high frequency waveform. In this way, power delivery can be regulated to maintain a given set temperature. This flow is represented by element 39, which is simply a feedback control device. The dotted lines from element 39 to elements 40 and 41 represent a feedback connection that could either be electronic and/or mechanical. It could also simply be a person operating these controls manually, based on the visual display of temperature, as for example on a meter or graphic display readout 42.

As was explained with respect to the disclosed embodiments, many variations of circuit design, modulated high frequency waveforms, electrode applicators, electrode cannulas will be appreciated by those skilled in the art. For example, electrodes or electrode applicators are practical, including tubular shapes, square shafts, flat electrodes, area electrodes, multiple electrodes, arrays of electrodes, electrodes with side outlets or side-issued tips, electrodes with broad or expandable or conformal tips, electrodes that can be implanted in various portions of the brain, spinal cord, interfecal space, interstitial or ventricular spaces, nerve ganglia can be considered within the system of the present invention.

The frequency range for the so-called high frequency waveforms, as shown for instance in Figures 2, 3, 4, and 5 can be used over a wide range. For example, the "high frequency" characteristic of 1/T3, which may be only one of many high frequency components, can be above the so-called physiologic stimulation frequency range of 0 to about 300 Hertz. This high frequency may also range up

into the radiofrequency or microwave range (viz. 50 Kilo Hertz to many Mega Hertz).

Mixtures of frequencies can be done as discussed above. These could be admixtures of "high frequencies" (above the physiologic stimulation range (say 0 to 300 Hertz) and lower frequencies (within that stimulation range of say 0 to 300 Hertz). Thus one skilled in the art could have both modulated high frequency and stimulation frequencies for various clinical effects, such as stimulation blockage of pain while neural modification is being applied according to the present invention.

In view of these considerations, as will be appreciated by persons skilled in the art, implementations and systems should be considered broadly and with reference to the claims set forth below.

ABSTRACT OF THE DISCLOSURE

A method and apparatus for altering a function of neural tissue in a patient. An electromagnetic signal is applied to the neural tissue through an electrode. The electromagnetic signal has a frequency component above the physiological stimulation frequency range and an intensity sufficient to produce an alteration of the neural tissue and a waveform that prevents lethal temperature elevation of the neural tissue during application of the electromagnetic signal to the neural tissue.

Claims:

1. An apparatus for altering the function of neural tissue in a patient comprising:

a) an electrode adapted to apply an electromagnetic signal to said neural tissue;

b) a signal generator that generates an electromagnetic signal having at least one frequency component above the physiologic stimulation frequency range, said frequency component having sufficient intensity to produce an alteration of said neural tissue, and said electromagnetic signal having a waveform that prevents heating of said neural tissue above a lethal thermal level when said electromagnetic signal is applied to said neural tissue through said electrode; and,

c) an electromagnetic coupling of said signal generator and said electrode.

2. The apparatus of claim 1 further comprising:

a temperature sensor that senses the temperature of the neural tissue and produces an output signal representative of said temperature; and,

a frequency component intensity control responsive to the output signal from the temperature sensor, said intensity control adjusting the intensity of the frequency component to maintain the temperature of the neural tissue below said lethal thermal level when said electromagnetic signal is applied to said neural tissue.

3. The apparatus of claim 1 wherein said electromagnetic signal is a radiofrequency signal.

4. An apparatus for altering a function of neural tissue in a patient comprising:

a) an electrode adapted to apply an amplitude modulated signal to the neural tissue of the patient;

b) a signal generator that generates an amplitude modulated signal having at least one frequency component above a physiological stimulation frequency range, said amplitude modulated signal producing an alteration of a function of the neural tissue while producing an average power deposition in the neural tissue corresponding to non-lethal temperature elevation of said neural tissue when the amplitude modulated signal is applied to the neural tissue through said electrode; and,

c) an electromagnetic coupling between said signal generator and said electrode.

5. The apparatus of claim 4 further comprising:
a modulation amplitude control that adjusts the amplitude of the signal modulation; and,
a duty cycle control that adjusts a ratio of signal ON time to signal OFF time.

6. The apparatus of claim 4 wherein the amplitude modulated signal has a peak voltage in the range of 10-30 volts with a waveform having a total period of one second with an ON time in the range of 10-30 milliseconds and a corresponding OFF time of 990-970 milliseconds.

7. A method for altering the function of neural tissue in a patient comprising the steps of:

a) generating an electromagnetic signal having at least one frequency component above the physiologic stimulation frequency range, said frequency component having sufficient intensity to produce an alteration of said neural tissue, and said electromagnetic signal having a waveform that prevents heating of said neural tissue above lethal thermal levels when said electromagnetic signal is applied to said neural tissue; and,

b) applying said electromagnetic signal to said neural tissue:

8. The method of claim 7 further comprising the steps of:

a) sensing the temperature of the neural tissue;

b) generating a temperature signal representative of the sensed temperature of the neural tissue; and,

c) adjusting the intensity of the frequency component in response to said temperature signal in order to maintain the temperature of the neural tissue below said lethal thermal level when said electromagnetic signal is applied to said neural tissue.

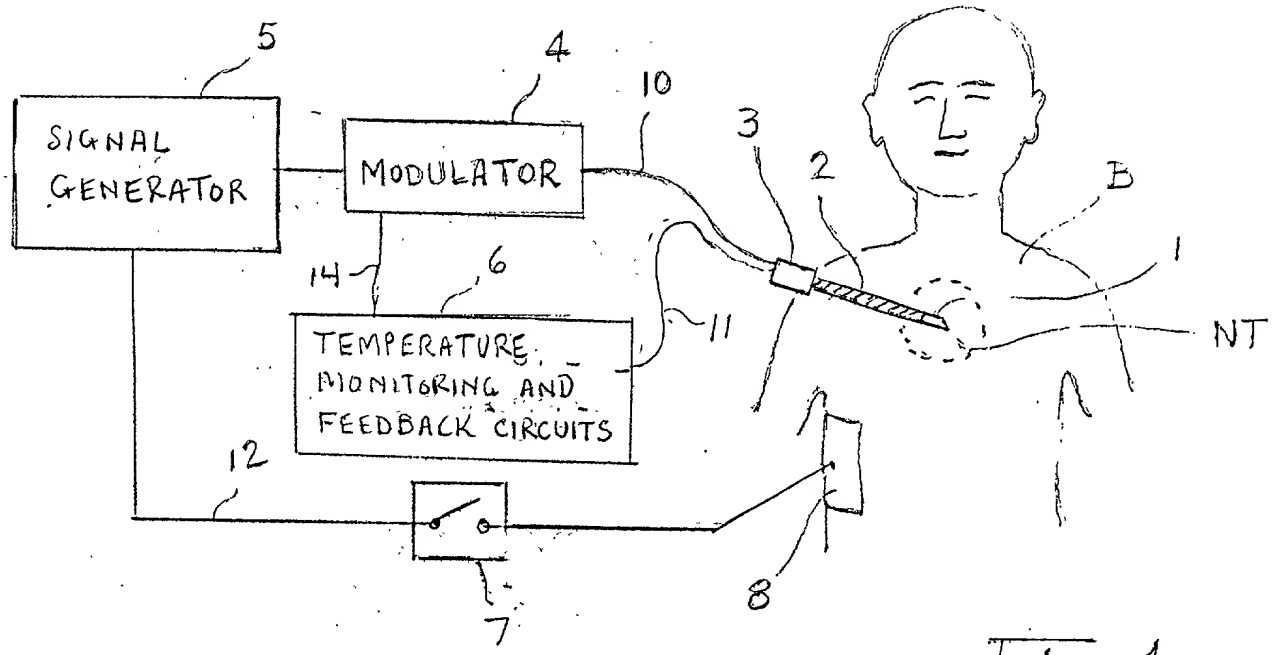

Fig. 1

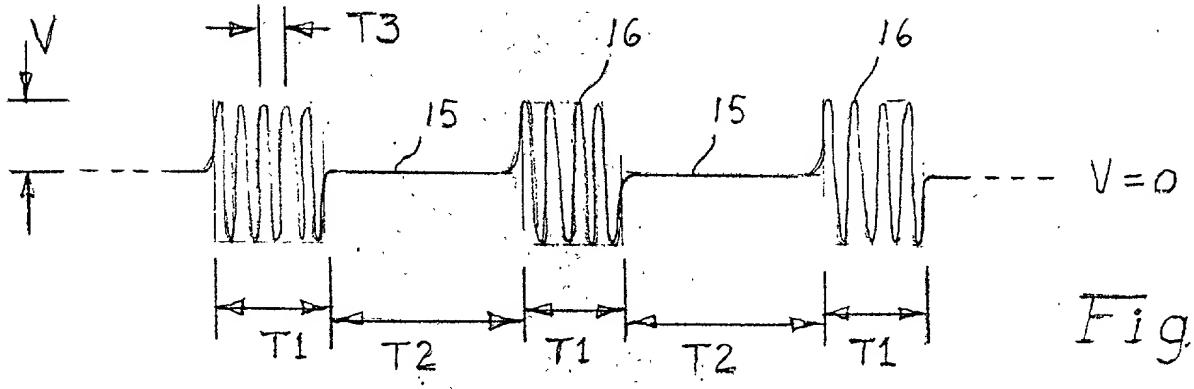

Fig. 2

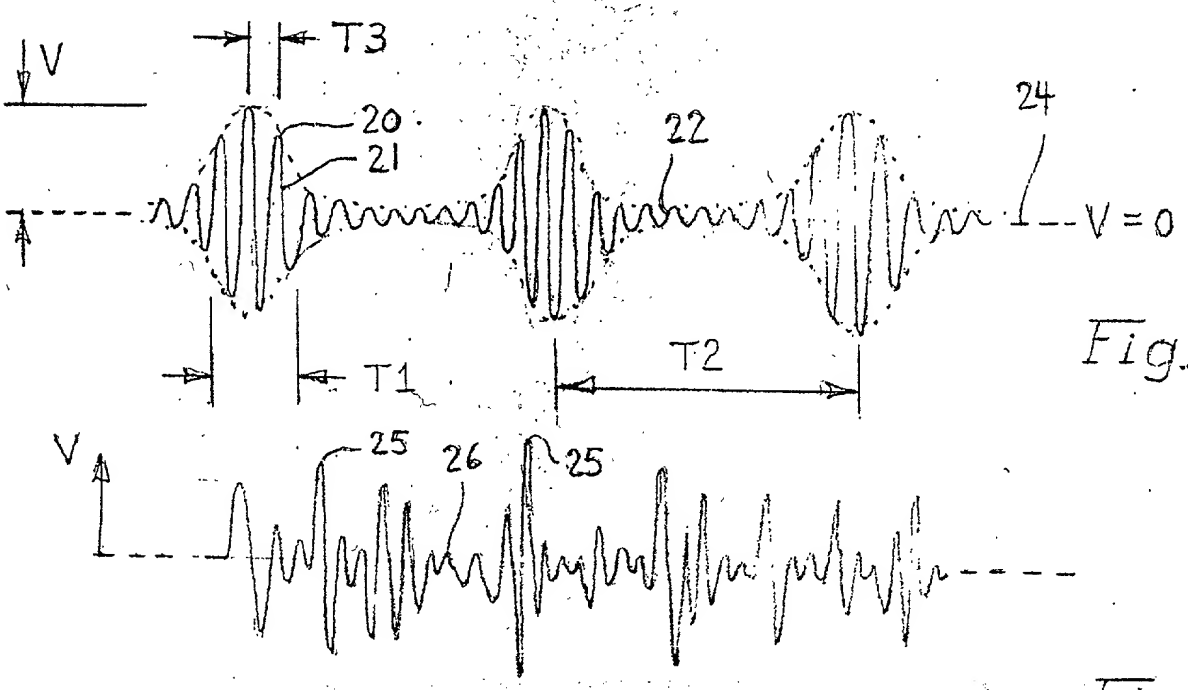

Fig. 3

Fig. 4

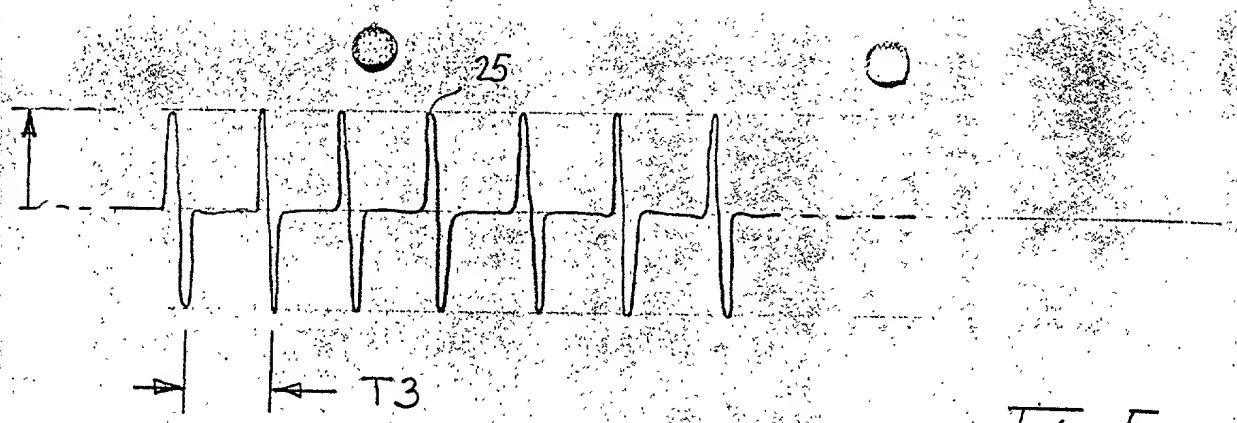
25
V
T3

Fig.5

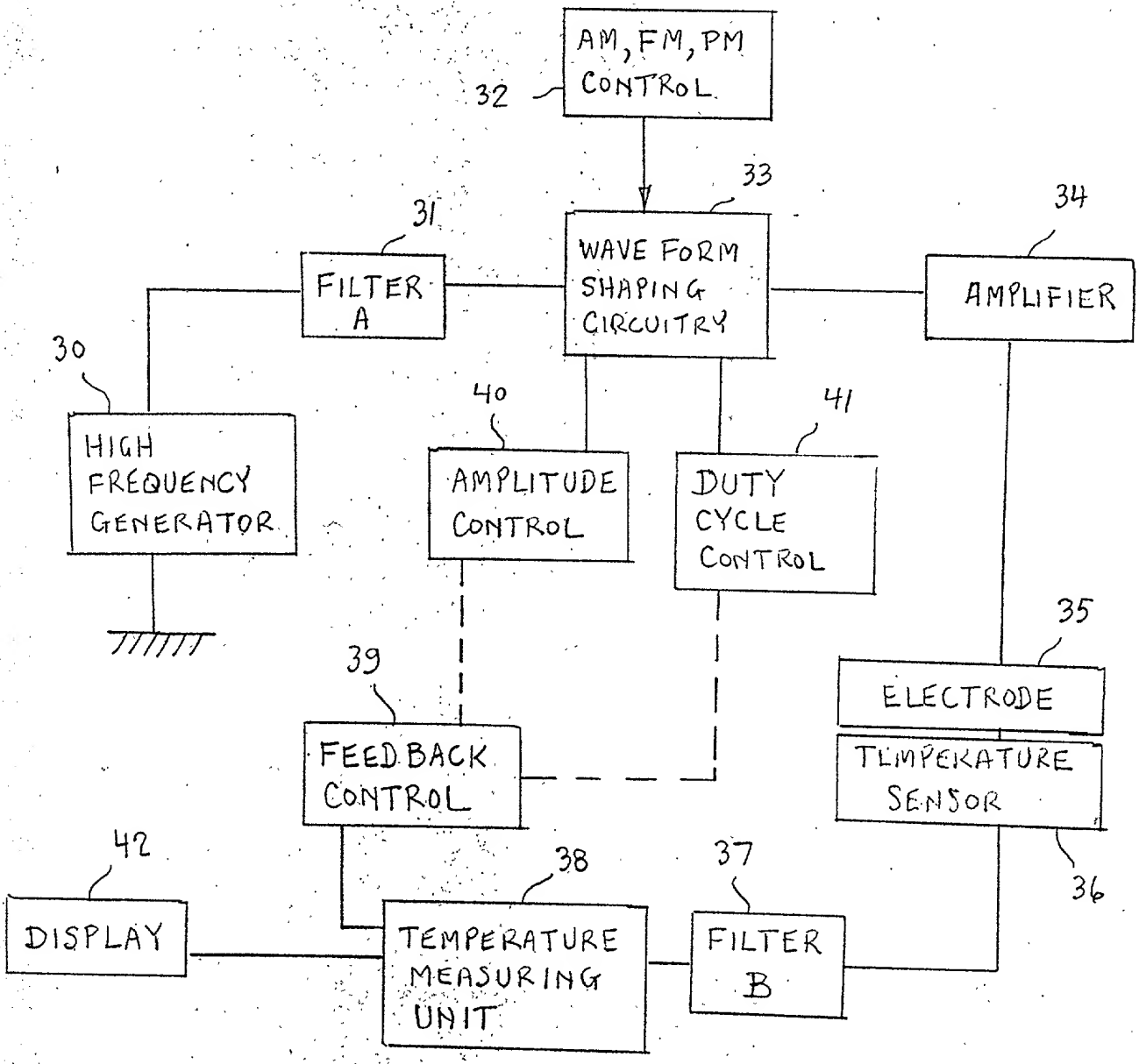
AM, FM, PM CONTROL
32
33
31
34
WAVE FORM SHAPING CIRCUITRY
FILTER A
AMPLIFIER
30
40
41
HIGH FREQUENCY GENERATOR
AMPLITUDE CONTROL
DUTY CYCLE CONTROL
35
39
ELECTRODE
FEED BACK CONTROL
TEMPERATURE SENSOR
42
38
37
36
DISPLAY
TEMPERATURE MEASURING UNIT
FILTER B

Fig. 6

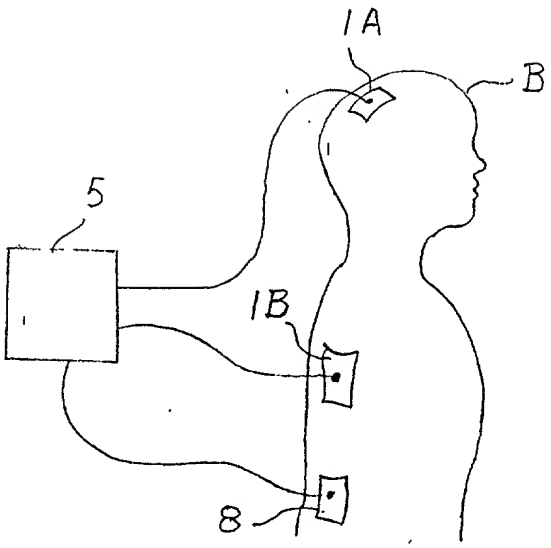

FIG. 7

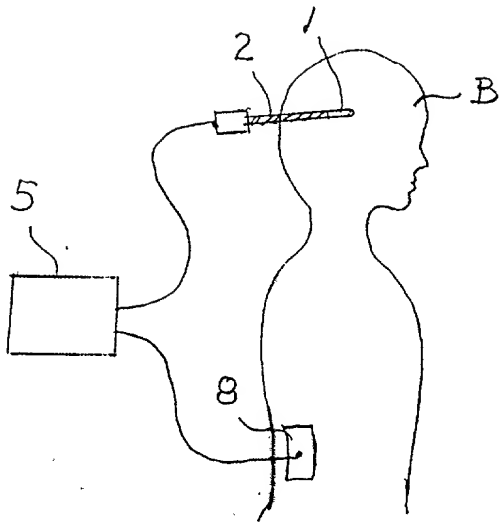

FIG. 8

Attorney's Docket No. _____ **PATENT**

COMBINED DECLARATION AND POWER OF ATTORNEY

(ORIGINAL, DESIGN, NATIONAL STAGE OF PCT, SUPPLEMENTAL, DIVISIONAL, CONTINUATION OR C-I-P)

As a below named inventor, I hereby declare that:

TYPE OF DECLARATION

This declaration is of the following type:

(check one applicable item below)

- ☒ original.
- ☐ design.
- ☐ supplemental.

NOTE: If the declaration is for an International Application being filed as a divisional, continuation or continuation-in-part application, do not check next item; check appropriate one of last three items.

- ☐ national stage of PCT.

NOTE: If one of the following 3 items apply, then complete and also attach ADDED PAGES FOR DIVISIONAL, CONTINUATION OR C-I-P.

- ☐ divisional.
- ☐ continuation.
- ☐ continuation-in-part (C-I-P).

INVENTORSHIP IDENTIFICATION

WARNING: *If the inventors are each not the inventors of all the claims, an explanation of the facts, including the ownership of all the claims at the time the last claimed invention was made, should be submitted.*

My residence, post office address and citizenship are as stated below, next to my name. I believe that I am the original, first and sole inventor *(if only one name is listed below)* or an original, first and joint inventor *(if plural names are listed below)* of the subject matter that is claimed, and for which a patent is sought on the invention entitled:

TITLE OF INVENTION

METHOD AND APPARATUS FOR ALTERING NEURAL TISSUE FUNCTION

EXPRESS MAIL LABEL NO. EL171836505US

DATE OF DEPOSIT Oct. 6, 1999

SPECIFICATION IDENTIFICATION

the specification of which:

(complete (a), (b) or (c))

(a) ☐ is attached hereto.

NOTE: *"The following combinations of information supplied in an oath or declaration filed on the application filing date with a specification are acceptable as minimums for identifying a specification and compliance with any one of the items below will be accepted as complying with the identification requirement of 37 CFR 1.63:*

"(1) name of inventor(s), and reference to an attached specification which is both attached to the oath or declaration at the time of execution and submitted with the oath or declaration on filing;

"(2) name of inventor(s), and attorney docket number which was on the specification as filed; or

"(3) name of inventor(s), and title which was on the specification as filed."

Notice of July 13, 1995 (1177 O.G. 60).

(b) ☒ was filed on June 27, 1996, as ☒ Serial No. 08/ 671,927 or ☐ _____ and was amended on _____ *(if applicable).*

NOTE: *Amendments filed after the original papers are deposited with the PTO that contain new matter are not accorded a filing date by being referred to in the declaration. Accordingly, the amendments involved are those filed with the application papers or, in the case of a supplemental declaration, are those amendments claiming matter not encompassed in the original statement of invention or claims. See 37 CFR 1.67.*

NOTE: *"The following combinations of information supplied in an oath or declaration filed after the filing date are acceptable as minimums for identifying a specification and compliance with any one of the items below will be accepted as complying with the identification requirement of 37 CFR 1.63:*

"(1) name of inventor(s), and application number (consisting of the series code and the serial number; e.g.,08/123,456);

"(2) name of inventor(s), serial number and filing date;

"(3) name of inventor(s) and attorney docket number which was on the specification as filed;

"(4) name of inventor(s), title which was on the specification as filed and filing date;

"(5) name of inventor(s), title which was on the specification as filed and reference to an attached specification which is both attached to the oath or declaration at the time of execution and submitted with the oath or declaration; or

"(6) name of inventor(s), title which was on the specification as filed and accompanied by a cover letter accurately identifying the application for which it was intended by either the application number (consisting of the series code and the serial number; e.g.,08/123,456), or serial number and filing date. Absent any statement(s) to the contrary, it will be presumed that the application filed in the PTO is the application which the inventor(s) executed by signing the oath or declaration."

Notice of July 13, 1995 (1177 O.G. 60).

(c) ☐ was described and claimed in PCT International Application No. _____, filed on _____ and as amended under PCT Article 19 on _____ *(if any).*

ACKNOWLEDGEMENT OF REVIEW OF PAPERS AND DUTY OF CANDOR

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information, which is material to patentability as defined in 37, Code of Federal Regulations, § 1.56,

(also check the following items, if desired)

☒ and which is material to the examination of this application, namely, information where there is a substantial likelihood that a reasonable Examiner would consider it important in deciding whether to allow the application to issue as a patent, and

☐ in compliance with this duty, there is attached an information disclosure statement, in accordance with 37 CFR 1.98.

PRIORITY CLAIM (35 U.S.C. § 119(a)–(d))

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(a)–(d) of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed.

(complete (d) or (e))

(d) ☒ no such applications have been filed.

(e) ☐ such applications have been filed as follows.

NOTE: Where item (c) is entered above and the International Application which designated the U.S. itself claimed priority check item (e), enter the details below and make the priority claim.

PRIOR FOREIGN/PCT APPLICATION(S) FILED WITHIN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO THIS APPLICATION AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. § 119(a)-(d)

COUNTRY (OR INDICATE IF PCT)	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 37 USC 119
			☐ YES NO ☐
			☐ YES NO ☐
			☐ YES NO ☐
			☐ YES NO ☐
			☐ YES NO ☐

CLAIM FOR BENEFIT OF PRIOR U.S. PROVISIONAL APPLICATION(S)
(34 U.S.C. § 119(e))

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below:

PROVISIONAL APPLICATION NUMBER	FILING DATE
_____ /_____	_____
_____ /_____	_____
_____ /_____	_____

CLAIM FOR BENEFIT OF EARLIER US/PCT APPLICATION(S) UNDER 35 U.S.C. 120

☐ The claim for the benefit of any such applications are set forth in the attached ADDED PAGES TO COMBINED DECLARATION AND POWER OF ATTORNEY FOR DIVISIONAL, CONTINUATION OR CONTINUATION-IN PART (C-I-P) APPLICATION.

ALL FOREIGN APPLICATION(S), *IF ANY*, FILED MORE THAN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO THIS U.S. APPLICATION

NOTE: *If the application filed more than 12 months from the filing date of this application is a PCT filing forming the basis for this application entering the United States as (1) the national stage, or (2) a continuation, divisional, or continuation-in-part, then also complete ADDED PAGES TO COMBINED DECLARATION AND POWER OF ATTORNEY FOR DIVISIONAL, CONTINUATION OR C-I-P APPLICATION for benefit of the prior U.S. or PCT application(s) under 35 U.S.C. § 120.*

POWER OF ATTORNEY

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

(list name and registration number)

Richard J. Birch, Reg. No. 20,895

(check the following item, if applicable)

☐ Attached, as part of this declaration and power of attorney, is the authorization of the above-named attorney(s) to accept and follow instructions from my representative(s).

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Richard J. Birch
Suite 125
20 William Street
Wellesley, MA 02181

DIRECT TELEPHONE CALLS TO:
(Name and telephone number)

Richard J. Birch
617-237-1819

DECLARATION

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

SIGNATURE(S)

NOTE: Carefully indicate the family (or last) name, as it should appear on the filing receipt and all other documents.

Full name of sole or first inventor

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Inventor's signature [signature]

Date 9/10/96 **Country of Citizenship** Netherlands

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Inventor's signature [signature]

Date 8/29/96 **Country of Citizenship** U.S.A.

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Eric (GIVEN NAME) R. (MIDDLE INITIAL OR NAME) Cosman (FAMILY (OR LAST NAME))

Inventor's signature [signature]

Date 8-29-96 **Country of Citizenship** U.S.A.

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Post Office Address 872 Concord Avenue, Belmont, MA 02178

(check proper box(es) for any of the following added page(s) that form a part of this declaration)

☐ **Signature** for fourth and subsequent joint inventors. *Number of pages added* _____.

* * *

☐ **Signature** by administrator(trix), executor(trix) or legal representative for deceased or incapacitated inventor. *Number of pages added* _____.

* * *

☐ **Signature** for inventor who refuses to sign or cannot be reached by person authorized under 37 CFR 1.47. *Number of pages added* _____

* * *

☐ Added page for **signature** by one joint inventor on behalf of deceased inventor(s) where legal representative cannot be appointed in time. (37 CFR 1.47)

* * *

☐ Added pages to combined declaration and power of attorney for divisional, continuation, or continuation-in-part (C-I-P) application.

☐ Number of pages added _____

* * *

☐ Authorization of attorney(s) to accept and follow instructions from representative.

* * *

(if no further pages form a part of this Declaration, then end this Declaration with this page and check the following item)

☒ This declaration ends with this page.

Attorney Docket No. 108155.117 PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s): Menno E. Sluijter et al.

Serial No.: 08/671,927

Filed: June 27, 1996

For: METHOD AND APPARATUS FOR ALTERING NEURAL TISSUE FUNCTION

Assistant Commissioner for Patents
Washington, D.C. 20231

ASSOCIATE POWER OF ATTORNEY (37 CFR 1.34)

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EXPRESS MAIL LABEL NO. EL171836505US

DATE OF DEPOSIT Oct. 1, 1998